

Biomim Column Treatment Design Tutorial

This tutorial explains how Biomim column data available elsewhere on this web site can be used to design a treatment system for a wastewater stream. To use this tutorial, you will need to know the approximate wastewater flow rate (e.g. liters per minute or gallons per hour), the pollutant(s) that need to be removed, and the percent removal required. For the purposes of this tutorial, we will use example data for oil removal from water using a EC-199 sorbent.

Disclaimer: Please note that these design calculations are approximate. Differences in water chemistry from actual systems and our laboratory data may result in differences between the predicted system performance and the actual system performance. This tutorial is designed to be a guide for initial design and for estimating sorbent material costs.

As an example, consider the data below for oil removal from a column of EC-199. These data are in the same format as data for other sorbents and pollutants on the Biomim website. For our design calculations, only a few pieces of information are required from Table 1 and Figure 1 below to begin our calculations.

From Table 1, we will need to know the porosity, $n = 0.3$. The porosity is the volume of void space (V_v) in the column divided by the total volume (V_t) of the column. When the column is saturated with water, the void space (V_v) equals the volume of water in the column.

We will also need to read a value off the graph in Figure 1. To do this, we need to know the desired oil removal rate. For example, let's say that the wastewater has an oil concentration of 8.34 lb/gal (1000 mg/L) and it needs to be reduced to at least 1.67 lb/gal (200 mg/L) or less. Changing the concentration from 8.34 lb/gal to 1.67 lb/gal means that the effluent oil concentration is only 20% of the influent concentration, or, the normalized effluent concentration is 1.67 lb/gal divided by 8.34 lb/gal, or 0.2. When the normalized concentration reaches 0.2, we will have to change the sorbent (or in some cases, regenerate the existing sorbent).

Using a target normalized concentration of 0.2, we can find that value on the vertical axis of the graph in Figure 1 and move horizontally across the graph until we reach the S-shaped curve. Dropping down vertically from this point, we read a pore volume value of about 450 from the horizontal axis.

We now have the following two numbers required for our design calculations:

Porosity = $n = 0.3$

Pore Volumes (corresponding to 80% oil removal) = $PV = 450$

Table 1. Sorbent mass, porosity, flow rate and residence time information for the EC-199 column experiments.

Sorbent	Mass Sorbent		Porosity	Flow Rate		Residence
	(kg)	(lb)		(mL/min)	(gal/hr)	
EC-199	0.123	0.28	0.30	15.1	0.24	6.57

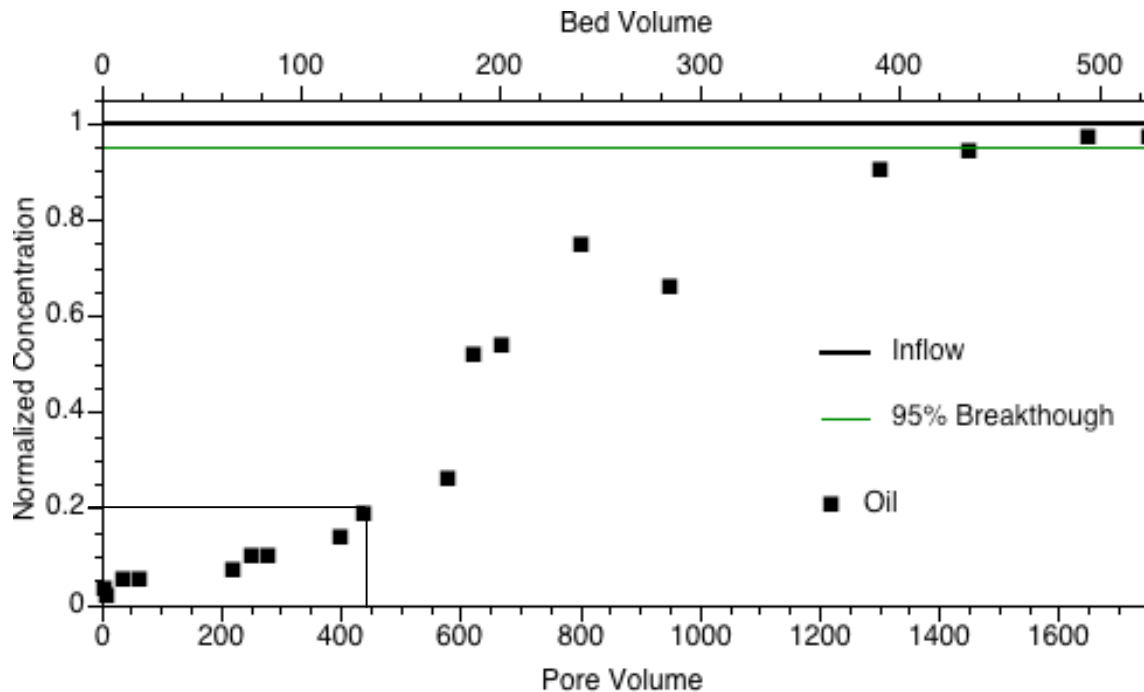


Figure 1. Breakthrough curve of oil through a column of EC-199

We will now use these two numbers, along with the wastewater flow rate, to calculate column volume and the schedule for replacing (or regenerating) the sorbent. These two design variables are related. For example, a bigger column will need to have the sorbent changed/regenerated on a less frequent basis than a smaller column. Therefore, based on maintenance schedules and available space, each user will have some flexibility in choosing specific values. This will be demonstrated as we proceed through this example.

First, it will help us to understand the physical meaning of the pore-volume value (= 450) that we read off the graph in Figure 1. This number means that after a volume of water flows through the column equal to $450 \times V_v$ (the void volume in the column), it will be time to change/regenerate the sorbent in the column.

Assuming that your wastewater flow rate is $Q = 949.87$ gal/d (3,600 L/day), and you would only like to change/regenerate your sorbent once every $t_r = 180$ days, your total column volume, V_t , can be calculated as follows:

$$V_t = \frac{t_r Q}{(PV)n} \quad (1)$$

Plugging specific numbers gives the following:

$$V_t = [(180 \text{ days})(949.87 \text{ gal/day})]/[(450 \text{ pore volume})(0.3)] = 1266.49 \text{ gal} \quad (2)$$

1266.49 (4800 L=4.8 m³) a column with a 11.67 ft (3.5-m) height and 4.40 ft (1.32-m) diameter would allow sufficient volume to only require a sorbent change/regeneration every 180 days.

As illustrated by the above equations, V_t and t_r are directly proportional. So, if you decide instead to only change your sorbent every 90 days instead of every 180 days, then your required tank volume will be cut in half to 633.25 gal (2400 L).

Now that your tank volume has been determined, you will need to determine how much Biomin sorbent must be purchased to fill the tank. The sorbent mass required, M_s , can be determined as follows:

$$M_s = V_t (15.84 \text{ lb/gal}) = (1266.49 \text{ gal})(15.84 \text{ lb/gal}) = 20,061.25 \text{ lbs}$$

The above equation assumes that the sorbent-filled column will have a dry bulk density of 15.84 lb/gal (1.9 g/cm³). This value is approximate and may vary depending on how the column is packed. A list of the dry bulk density for several adsorbent material manufactured by Biomin, can be found at the “Biomin Adsorbent Chart” included at the end of this document.

Finally, it is useful to note that one additional design variable should be considered. This is the hydraulic retention (or residence) time, θ_t . Qualitatively, it is defined as the average time the treated water resides in the treatment column. Quantitatively, it is defined as follows:

$$\theta_t = \frac{nV_t}{Q}$$

For our example problem, $\theta_t = (0.3)(1266.49 \text{ gal}) / 949.87 \text{ gal/d} = 0.4 \text{ days}$ (9.6 hours). Therefore, for this flow rate and column size, the water resides in the column an average of 0.4 days. Before completing a design, the calculated hydraulic retention time should be compared to the hydraulic retention time used in the Biomin report for this sorbent-pollutant combination. Referring back to Table 1, we see that the experimental hydraulic retention time is 6.57 minutes. In general, the design hydraulic retention time should be greater than or equal to the experimental hydraulic retention time. In this example, since 0.4 days is much greater than 6.57 minutes, the design is acceptable.

Finally, in considering your design, you should realize that the magnitude of the pollutant concentration may also affect your design. The Biomin experiments published on this

website typically only consider a single influent pollutant concentration. In our design analyses, we have made certain assumptions (beyond the scope of this tutorial) regarding linear sorption. In some cases, the sorbents may perform better than expected for lower influent solute concentrations (compared to the experimental solutions) and worse for higher influent solute concentrations. This may require design adjustments in the wastewater flow rates, column size, or lifetime of the sorbent.

Biomin Adsorbent Chart

Contaminant	Form	Adsorbent	Porosity	Density (lb./gal)
Ammonium	Cation	EC-MCL	0.29	8.6
Arsenate	Anion	EC-MB	0.29	5.6
Cadmium	Cation	EC-MCL	0.3	8.6
Cadmium	Cation	EC-MB	0.4	5.6
Chromate	Anion	EC-MB	0.56	5.6
Chromium	Cation	EC-MCL	0.3	8.6
Chromium	Cation	EC-MB	0.38	5.6
Copper	Cation	EC-MCL	0.34	8.6
Copper	Cation	EC-MB	0.39	5.6
Fluoride	Anion	EC-MB	0.34	5.6
Fulvic Acid	Organic	TC-75	0.30	5.0
Humic Acid	Organic	TC-75	0.28	5.0
Iron	Cation	EC-MCL	0.31	8.6
Iron	Cation	EC-MB	0.4	5.6
Lead	Cation	EC-MCL	0.38	8.6
Lead	Cation	EC-MB	0.4	5.6
Mercury	Cation	EC-MCL	0.46	8.6
Nickel	Cation	EC-MCL	0.5	8.6
Nickel	Cation	EC-MB	0.4	5.6
Oil, Vegetable	Organic	EC-199	0.30	3.3
Phenol	Organic	Oilsorb	0.16	4.2
Phosphate	Anion	EC-MB	0.41	5.6
Selenite	Anion	EC-MB	0.46	5.6
Silica	Anion	EC-MCL	0.48	8.6
Tannic Acid	Organic	TC-75	0.30	5.0
Zinc	Cation	EC-MCL	0.34	8.6
Zinc	Cation	EC-MB	0.4	5.6